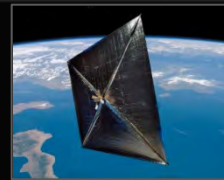
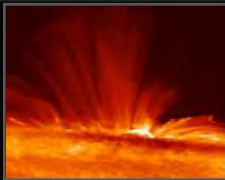




Marshall Space Flight Center

Launching the future of science and exploration

marshall



Marshall Space Flight Center

Marshall has the engineering expertise to ensure our nation can send humans beyond Earth and into deep space.

- Our unique capability is in large scale, complex space systems development with a core expertise in propulsion.
- We advance space technologies, spark economic development, expand our knowledge, and inspire a new generation of explorers.

Marshall's Core Capabilities and Services



Propulsion Systems



Space Transportation & Launch Systems

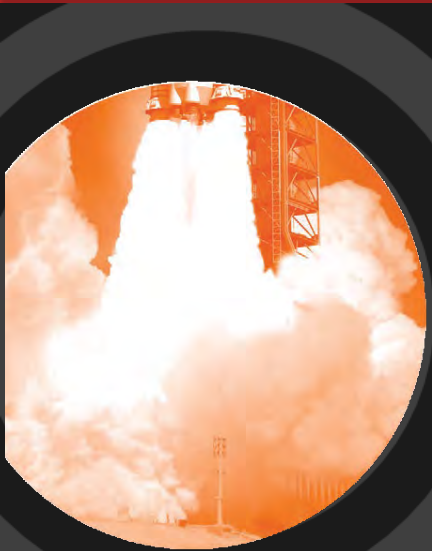


Space Systems



Scientific Research

Propulsion Systems



Marshall researches, develops, tests, and sustains propulsion systems and technologies for both Earth-to-orbit launch and in-space missions. We contribute engineering expertise for all phases of space transportation, including boost, upper stage, and in-space applications.

- Engines and solid rocket motors, from micro-thrusters to systems producing millions of pounds of force.
- Advanced propulsion and power research including high-power electric, nuclear and propellant-free systems, such as solar sails and electrodynamic tethers.
- Propulsion component design and development including advanced rotating machinery, injectors, nozzles, pre-burners, and ignition systems, valves, actuators, and thrust vector control systems.

Space Transportation & Launch Vehicles



Marshall capabilities and expertise support every stage of spacecraft and launch vehicle development and operations. Expert teams at Marshall develop, test, and evaluate materials, processes, designs, and systems, as well as full-up vehicles, such as the nation's new Space Launch System (SLS).

- System design, analysis, and testing of structural, avionics, and flight mechanics systems.
- End-to-end systems engineering to integrate spacecraft and vehicles with ground processing and launching facilities.
- Vehicle technical design and verification, from concept through post-flight assessments.
- Sustaining engineering support to space transportation systems through the decades that their operational life-cycle may encompass.

Space Systems



Marshall supports the Agency in developing large space structures and their supporting space systems, and has supported development of the Lunar Roving Vehicle, Skylab, Spacelab, and space station modules. Marshall also develops and manages small satellite projects and scientific payloads on a variety of spacecraft.

We develop, test, and manage:

- Logistics modules and connecting nodes
- Environmental Control and Life Support System
- Our Payload Operations Center, the space station's primary science command post
- Materials Science Research Rack experiment integration
- Microgravity Science Glovebox
- Development of science payloads

Scientific Research



Marshall develops, tests, and manages scientific instruments, experiments, and spacecraft that gather vital information about Earth and space.

Our scientists:

- Seek to understand dark matter and dark energy through X-ray astronomy investigations and studies of gamma-ray bursts and cosmic rays.
- Study and predict the sun's dynamics to improve forecasts of the solar eruptions and space weather that can affect humans
- Develop tools to provide better monitoring and prediction of Earth's weather, climate and other environmental impacts.
- Study planetary atmospheres, interiors, and histories.

A cosmic scene featuring the Earth's horizon at the bottom, the Moon in the center, and Mars in the upper right, set against a backdrop of a colorful nebula and distant stars.

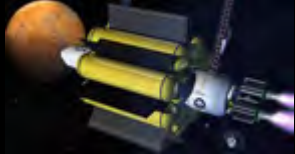
Marshall engineering expertise...
from ideas to innovation

Engineering Directorate Overview

Engineering Disciplines

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Advanced Concepts



- Concept Definition, Integration, & Analysis
- Earth-to-Orbit Transportation
- In-Space Transportation
- Habitation & Crew Systems
- Science & Robotic Exploration
- Architecture Analysis
- Technology Assessments

Space Systems



- Instruments & Payloads
- Environmental Control & Life Support Systems
- Electronics
- Software
- Small Mechanical Systems
- Fabrication & Assembly Services

Spacecraft & Vehicle Systems



- Systems Engineering & Integration
- Tank/Structures Design
- Loads & Dynamics
- Mechanisms
- Terrestrial & Space Environments
- Induced Environments
- Modeling & Simulation
- Guidance, Navigation, & Control

Propulsion Systems



- Propulsion Engineering
- Liquids & Solids
- Component Design
- Fluid Systems Design & Analysis
- Computational Fluid Mechanics
- In-Space Propulsion
- Nuclear Propulsion

Mission Operations



- Operation Concepts Development and Analysis
- Ground Operations, Supportability & Logistic SE&I
- Mission Operations Planning, Training and Execution
- Operations Facility Management
- Ground Systems Research and Development

Materials & Processes



- Metallics
- Composites
- Ceramics
- Environmental Effects
- Fracture & Failure Analysis
- NDE & Tribology
- Chemistry & Combustion Research

Test Lab



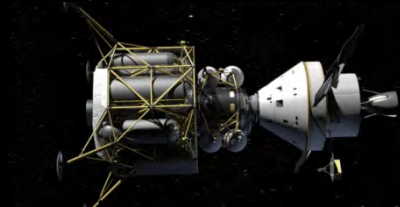
- Propulsion Testing
- Structural Testing
- Thermal Vacuum
- Shock & Vibration
- Acoustic
- Experimental Fluids Test & Development
- Advanced Instrumentation Application

Earth to Orbit Concept Definition & Analysis



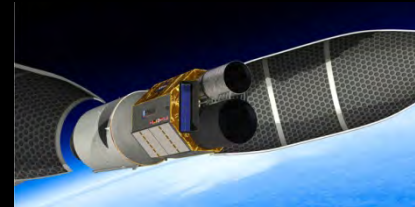
- Earth to Orbit Trajectory Analysis
- Weights & Sizing
- Vehicle Structural Analysis
- System Level Trades

In-Space Systems Analysis



- Architecture Analysis
 - Concept of Operations
 - Mission Analysis
- Technology Assessments
- In Space Element Definition
- Habitation & Crew System

Analysis, Mission Concept Definition and Spacecraft Concepts



- Scientific & Robotic Exploration
 - Planetary Science
 - Earth Science
 - Heliophysics
 - Astrophysics
 - Human Exploration Precursors
- Human Exploration
- Technology Demonstrations

Space Systems Department

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Systems Engineering & Integration



- Lead Systems Engineers
- Hardware & Software Requirements & Verification
- System Level Trade Studies
- Avionics Systems Integration
- Engineering Discipline Interface
- Systems Engineering Management Plan

Mechanical Design, Analysis & Fabrication



- Strength Analysis
- Structural Dynamics & Loads Analysis
- Vibroacoustics
- Thermal Design & Analysis
- Mechanisms
- Fluid Systems Design & Analysis
- Modeling & Simulation
- Loads & Dynamics
- Mechanical Fabrication & Assembly

Avionics Design



- Instrumentation & Advanced Flight Sensors
- GN&C Hardware
- Imaging & Video Systems
- Embedded Control Systems
- Optics
- Flight & Ground Computers
- Data Systems
- RF Systems
- Communications

Electrical Integration & Fabrication



- Electrical Power Systems
- Electromagnetic Environmental Effects
- EMC Analysis
- Electrical Integration
- Electronic Fabrication & Assembly
- Electronic Packaging Design
- EEE Parts Analysis & Verification

Flight & Ground Software



- Mission-Critical Flight Software
- Propulsion Controllers
- Payload Flight Software
- Software Testing, Costing & Metrics
- Systems Integration Lab (SIL)
- Systems Integration & Test

Systems Development, Integration & Test



- Science Payload Hardware Development
- Systems Integration & Test
- Flight Experiment & Payload Operations
- Sub-orbital Flight Tests of "Breadboard" Instruments
- Water and Air Systems Development Testing
- ECLSS Flight Hardware Acceptance & Quality Testing
- Fluid System Design & Analysis (ECLSS)

Spacecraft & Vehicle Systems

Point of Contact:

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Systems Engineering & Integration



System Design

- Concept through post flight performance assessments

Element Integration

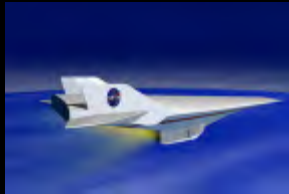
- Interconnects
- Ground stacking
- Launch facilities
- Operations process design

System Engineering

- Interface control
- Ground Operations
- Launch support
- Hardware Acceptance
- Stack Reviews
- Roll Out
- Flight Readiness

Major Integrated Development Milestones planning

Stage Engineering & Integration



Technical management & Planning

- Design
- Manufacture
- Assembly
- Test & Transport

Technical Characterization

- Applied Engineering Standards
- Empirical & Analytical analysis
- Systems Verification

Technical Design

- Concept through post-flight assessment

Development Milestones

Systems Engineering support

- Ground Operations
- Launch support
- Hardware Acceptance
- Stack Reviews
- Roll Out
- Flight Readiness

Structural Design & Analysis



Structural Dynamics, Loads & Stress Analysis

- Structural analysis
- Fracture mechanics
- Dynamics & Vibroacoustic environments

Structural & Mechanical Design & Modeling

- Pyrotechnic systems analysis
- Meteoroid debris analysis

Composite Structures

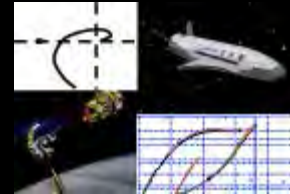
Aero sciences

- Aerodynamics
- Acoustic environments
- Rocket exhaust plume characterization
- Aerothermodynamics
- Venting

Thermal Design, Analysis & Control

- Thermal/fluid analysis
- Launch vehicle TPS,
- Spacecraft thermal analysis

Flight Mechanics and Analysis



Control Systems Design & Analysis

- Requirements Definition
- Development
- Verification
- Launch Vehicle & Spacecraft

Guidance & Trajectories

- Guidance laws
- Trajectory designs
- Mission analysis

Navigation Systems

Modeling & Simulation

Integrated Systems Health Management

- Architecture definition
- Algorithm development & modeling

Natural environments

- Terrestrial
- Planetary

Business Areas



Launch Vehicles & Spacecraft

- Space Shuttle
- Constellation/Ares
- Ares V
- Space Launch System
- International Space Station

Launch Platforms

- FastSat

Science

- Payloads
- Natural Environments

Technology

- Integrated Health Management
- Spacecraft
- Nan-Energetic Propulsion Project (NEPP)

Propulsion Systems Department

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Liquid Propulsion Systems Design & Integration



- Integrated Booster & Upper Stage Propulsion Systems
- Main Propulsion Systems Design & Analysis
- Engine Systems Analysis & Health Management
- Space Craft Propulsion System, Design, Analysis, & Testing
- Cryogenic Fluid Management Systems Design, Analysis, Controls and Testing for Long Term Storage
- Advanced Propulsion & Power Research & Development including: High Power Electric Propulsion, Nuclear Thermal Propulsion, Space Nuclear Power Systems, and Nuclear Surface Power Systems.

Solid Propulsion Systems



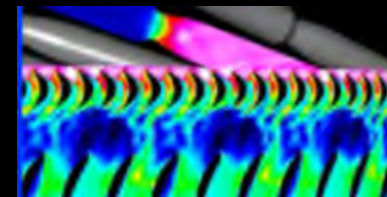
- Solid Boost Propulsion Systems Integration for Shuttle & CLV
- Separation & Maneuvering Solid Propulsion Systems Design and Development
 - Shuttle RSRB BSM
 - CLV RSRV Deceleration Motor & 1st Stage Tumbling Motor
 - CLV US Ullage Settling Motor
- Orion LAS Motors:
- System Ballistic Analysis

Propulsion Component Design & Development



- Turbomachinery Design, Analysis and Advanced Development
- Combustion Devices Design, Analysis and Advanced Development
 - Injectors, Thrust Chambers, Nozzles, Pre-burners, Gas Generators, and Ignition Systems
- Valves, Actuators, & Ducts Design, Analysis and Advanced Development
- Detail Component and System Design
- Thrust Vector Control Systems Design and Development

Propulsion Structural, Thermal, & Fluid Analysis



- Strength & Life Assessment
- Dynamic Loads & Data Analysis
- Flow Testing & Analysis (Steady & Unsteady)
- CFD of Turbomachinery (Pumps and Turbines)
- Water Flow & Air Flow Testing of Components
- Unsteady Fluid Dynamics Data Analysis, Acoustic Analysis & Combustion Instability Analysis
- Thermal analysis & design for liquids and solids
- CFD of combusting flows -liquid systems & solid motors

Mission Operations Laboratory

Point of Contact:
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Operations Concepts



- Provide operations engineering support
- Design for operability and affordability
- Develop end-to-end ops concepts and design reference missions
- Develop and analyze supportability & logistics concepts
- Assess feasibility and performance
- Perform life cycle ops cost analysis

Planning & Integration



- Develop operations processes, sequences and timelines
- Develop operations guidelines, requirements and constraints
- Develop manufacturing, integration and launch facility discrete event simulations
- Support integrated vehicle test operations
- Perform supportability and logistic engineering, analysis & integration
- Perform ground support equipment systems engineering
- Assess and integrate mission requirements

Training



- Plan and execute operations training templates & processes
- Perform crew and ground personnel training
- Develop flight procedures and displays
- Provide training systems
- Support vehicle & payload design team training needs

Existing Facility Capabilities



- Huntsville Operations Support Center (HOSC)
- Real time Command & Control (C&C) system
- Certified for hazardous commanding
- Level III secure facility
- Flexible remote access
- Expandable data reduction & storage
- Supports entire life cycle of projects - test phase to ops phase
- Remote C&C systems deployed worldwide

Realtime Operations



- Develop flight operations products
- Plan and manage operations resources
- Perform C&C for on-orbit flight systems
- Supervise flight operations
- Monitor flight operations safety
- Execute for mission success

Advanced Data Systems



- Continuous Innovation to reduce cost & increase ops capabilities
- Early Engineering support for development & test.
- Integrate Planning, Scheduling, & Realtime capabilities
- Research and develop interoperable C&C system of systems architectures
- Research and Develop Teleoperations & Telescience capabilities
- Research and Develop Automatic Scheduling Systems

Materials and Processes Laboratory

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Materials Testing



- Mechanical Properties
- Tribology Research
- Analytical & Environmental Chemistry
- Materials Compatibility
- Combustion Research
- Hydrogen Testing

Damage Tolerance Assessment



- Non-Destructive Evaluation
- Damage Tolerance Determinations
- Fracture Control Board
- Fracture Control & Analysis

Metals Engineering



- Materials Characterization
- Alloy Development
- Process Engineering
- Welding & Joining
- Corrosion & Plating
- Diagnostics & Failure Analysis

Environmental Effects



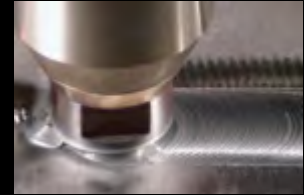
- Contamination & Foreign Object Debris
- Space Environmental Effects
- High Temperature Material Properties
- Impact Testing

Nonmetals Engineering



- Materials Characterization
- Polymers & Composites
- Ceramics & Ablatives
- Nonmetallic Processes
- Composites Manufacturing

National Center for Advanced Manufacturing (NCAM)



- Emerging Technologies for Manufacturing
- Intelligent Manufacturing
- Government, Industry, & Academic Partners

Test Laboratory

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Propulsion Test



- Sub-scale injectors & elements, thrusters, gas generators, turbopumps
- Oxygen & Hydrogen cold flow
- Cryostructural
- On-orbit vacuum environment
- Solar thermal propulsion
- Solid motor propellant & materials
- Hot gas material characterization
- Engine Systems (LH2, CH4, RP-1)

Experimental Fluid Dynamics Test



- Air & water flow
- Full flow air blow down for turbopump turbine inlet testing
- Subscale nozzle internal contours & back pressure data via blow down testing
- Pump impeller & inducer sub- & full-scale performance mapping via visual water flow testing
- Subsonic & supersonic vehicle model & nozzle testing at Mach 0.2-5.0
- Air blow down testing of subscale solid motor casing & nozzle designs
- Probe calibration testing

Environmental Test



- Thermal vacuum
- Thermal cycle/humidity
- Altitude
- Launch ascent/descent
- Vacuum bake out
- Optical certification bake out
- Arc Jet/Hot Gas
- Development, qualification, acceptance, & research testing of space flight hardware

Structural Strength Test



- Hazardous structural test
- Cryostructural test
- Tensile & compressive loads test
- Combined Environments
- Load environments to simulate launch, on orbit, & landing conditions for development, qualification, acceptance & research testing of space flight hardware

Structural Dynamics Test



- Experimental modal analysis to verify & correlate analytical finite element models of space flight hardware.
- Vibration, acoustic, & pyrotechnic shock testing for space flight hardware development, qualification & acceptance.
- Micro-gravity vibration emission testing

Test Support



- Propellants, Pressurants & Calibration
- Advanced Instrumentation Applications
- Special Test Equipment Design
- Test Planning
- Emerging Technologies
- Data System & Software Development

Timely Information for Programmatic Decisions

Conceptual Designs



- Modeling and Simulation Tools Inform “What If” Scenarios
- Designs for Space Systems, from Launch Vehicles to Science Instruments
- An Agency Asset Built on 50 Years of Reliable Data

Propulsion Research and Development



- J-2X Workhorse Gas Generator Testing
- Translating Component Performance and Reliability into System Affordability

One-of-a-Kind Testing Capabilities



- Robotic Lander Testbed Onboard Thrusters Controlled Descent
- Developed in a Record 10 months

***Solving Problems That Come Naturally With
New Technology Developments***

Technical Talent for Quick-Start Flexibility

Flight Testing



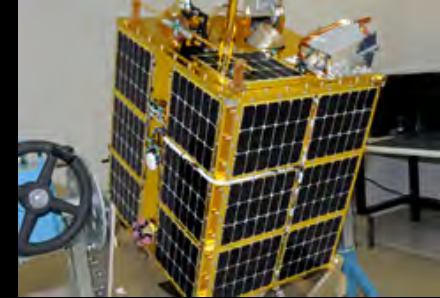
- Ares I-X Test Flight
- Repurposed Peacekeeper Hardware for an Innovative Application
- Delivered Roll Control System
- Rapidly Deployed an Agile, Integrated Team

Analysis of High-Value Hardware and Software Assets



- James Webb Space Telescope Mirrors
- Cryogenic Testing & Analysis

Small Spacecraft Development



- FASTSAT
- 18-Month development cycle
- Designed, Tested, Developed, and Certified for Flight
- Science Operations from Payload Operations Center

Engaging Highly Motivated Communities of Practice

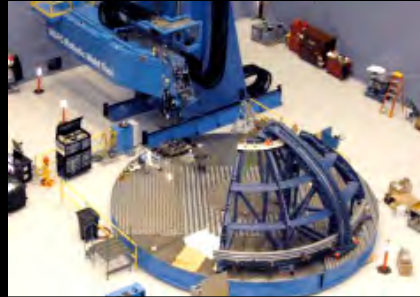
Designing for Efficient Operations

Propulsion Development



- Fastrac to Merlin Engine
- MSFC-developed propulsion technology
- Transitioned Technologies to Falcon 9
- 3-year Design and Development Cycle

Advanced Manufacturing



- Al-Li Spun Formed Dome
- Proving the Value of Friction-Stir Welding
- Investing in Highly Specialized Expertise
- Advancing manufacturing capabilities

Avionics



- Systems Integration Lab and Test Facility
- Flying Vehicle Concepts in Virtual Space
- Supporting Advanced Concepts and Mission Scenarios

***Reducing Risk and Raising Readiness Levels
for Complex, High-Payoff Technologies***

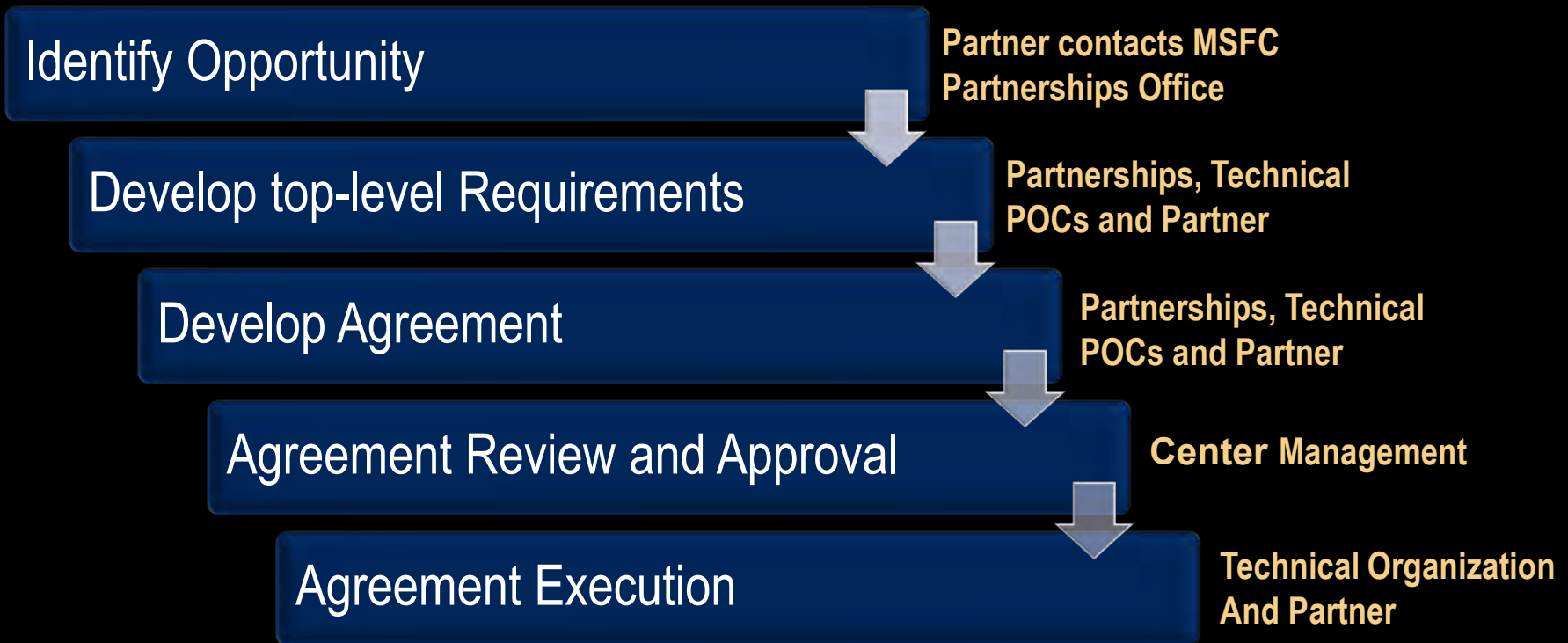
Marshall's Core Capabilities and Services

Marshall is a unique government workforce with detailed knowledge in

- Liquid and solid propulsion
 - Marshall contributes engineering expertise for all phases of space transportation, including boost, upper stage, and in-space applications.
- Space transportation and launch systems
 - Marshall capabilities and expertise support every stage of spacecraft and launch vehicle development and operations.
- Space systems
 - Marshall supports the Agency in developing large space structures and their supporting space systems, and develops and manages small satellite projects and scientific payloads on a variety of spacecraft.
- Scientific research
 - Marshall develops, tests, and manages scientific instruments, experiments, and spacecraft that gather vital information about Earth and space.

A tradition of collaboration and the “reach-back” capability to access other NASA installations and their expertise

How to Partner with Marshall



- Marshall has ongoing collaborative efforts with Department of Defense, traditional prime aerospace companies, and the emerging commercial spaceflight industry.
- Primarily effected through Space Act Agreement (SAA), Enhanced Use Lease Agreement (EUL), and MOAs
- Mature processes to develop and get agreements approved in a timely manner

Marshall Partnerships

Contact Marshall's Partnership Office:

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- Charlie Nola (256) 544-6367 charles.l.nola@nasa.gov
- Whitney Young (256) 544-0615 whitney.young@nasa.gov



www.nasa.gov/marshall